AN INDEPENDENT LOOK AT THE CONTROVERSY OF RELIABILITY IMPROVEMENT WARRANTIES

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THESIS

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by

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September 1979

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T190355

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): An Independent Look at the Controversy of Reliability Improvement Warranties	5. TYPE OF REPORT & PERIOD COVERED: Master's Thesis; September 1979
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Robert Lee Sweney	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Postgraduate School, Monterey, California 93940	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Postgraduate School, Monterey, California 93940	12. REPORT DATE: September 1979
	13. NUMBER OF PAGES: 76
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office): Naval Postgraduate School, Monterey, California 93940	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Warranty
Reliability Improvement Warranties
Acquisition Strategy
Guarantees
Life-Cycle Cost

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Reliability Improvement Warranty has grown in acceptance as a plausible contractual method of improving field reliability and reducing maintenance costs of military hardware. The acceptance of RIWs has not been universal, however, with many factions doubting the actual success and value of the RIW concept. Much confusion and uncertainty clouds warranty experimentation and more orderly progress is necessary to deter-

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S/N 0102-014-6601 |
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An Independent Look at the Controversy of Reliability Improvement Warranties

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

The Reliability Improvement Warranty has grown in acceptance as a plausible contractual method of improving field reliability and reducing maintenance costs of military hardware. The acceptance of RIWs has not been universal, however, with many factions doubting the actual success and value of the RIW concept. Much confusion and uncertainty clouds warranty experimentation and more orderly progress is necessary to determine the feasibility of future RIW expansion. This study examines the current issues of RIW development and the controversy that has arisen over its use. The aspects of expanding Reliability Improvement Warranties to shipboard equipments is also explored. Interviews with personnel in the reliability field, case studies and other reports are used to collect information on the facts and issues influencing the controversy. An attempt is made to distill these facts and issues and to place them into an orderly and understandable perspective. This is done with the hope that the value and future of Reliability Improvement Warranties might be more easily determined.

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I. INTRODUCTION

A. PROBLEM

The acquisition, maintenance, and manning of a modern defense system is becoming increasingly complex and expensive. The complexity and expense of weapons systems is not only exceeding our treasury's ability to acquire and support them but is also testing the ability of the military services to maintain them. The technology of today's weapons is pushing the state-of-the-art in electronic design and automation. Furthermore, the advancement continues at an unbelievable pace, allowing little opportunity for our checkbook or our military training programs to catch up. In order to achieve these rapid advances, the design emphasis seems to be placed on performance rather than reliability and maintainability in the field. In Fiscal Year 1976, the operational readiness rates for two Navy fighters were 46.5% for the F-4 and 27.8% for the F-14. At the same time, operation and maintenance (O&M) costs are rising rapidly [Ref. 11:1].

This continuing problem has resulted in numerous efforts to improve reliability and maintainability and reduce maintenance costs through improved weapons system design. The technique used by many Defense Acquisition Agencies to "buy" reliability is a warranty clause, popularly known as a Reliability Improvement Warranty (RIW).

B. OBJECTIVES OF THE RESEARCH

Over the past ten years, the RIW has grown in acceptance as a plausible contractual method of improving reliability and saving maintenance costs of weapon systems. This acceptance has not been uniform, however, with many factions doubting the actual success and continued usefulness of the concept. Within the Navy, the Naval Air Systems Command (NAVAIR) has been the sole developer and user of the RIW. Other procurement agencies and higher level officials continue to hold reservations concerning the merits of the RIW.

The purpose of this study was to examine the current issues in RIW development and usage and to organize the facts and impressions focusing on the future of RIW expansion. It is perceived that much confusion and uncertainty clouds the RIW experimentation and that more orderly progress is necessary to determine the possibility of future RIW expansion. If the facts and issues can be distilled from the surrounding confusion and placed into an orderly and understandable perspective, the value and future of RIW development may be more easily determined.

C. RESEARCH QUESTION

The original research question of this study centered around the feasibility of expanding the RIW concept into shipboard systems. Early research efforts revealed that a much broader question remained unanswered, upon which shipboard application might ultimately rest. Therefore, the thrust

of the research was revised. The primary research question of this study is: "Can the RIW concept be expected to accomplish the goals or results for which it is intended?" In attempting to answer this question, additional questions were addressed. What is the concept of RIW and its definition? What are the goals of the RIW? What examples can be analyzed to provide future decision making alternatives?

Since much controversy still remains regarding the actual value of RIWs for accomplishing the desired results at a beneficial cost, the question of expansion into new areas of application appears premature. If the RIW is proven ineffective or not cost effective, the question of expansion becomes moot. However, since research into the RIW issues uncovered some interesting facts on the narrower subject, the feasibility of shipboard application remained a secondary objective.

D. SCOPE, LIMITATIONS, AND ASSUMPTIONS

The scope of this research effort remained within the framework of the Navy and its particular aspects of RIW development. However, the Army and Air Force have provided much of the RIW research and contributions to the available literature. For this reason, many of the experiences and conclusions used in assembling this study were drawn from the other Services. Where possible, this material was applied toward the Navy aspects of the problems addressed.

This study was not intended to be exhaustive in all areas of warranties. Many facets of RIW research and many

unanswered questions were not explored. Only those matters pertaining to the objectives of this study were examined in depth. Because of this, additional research into specific areas or programs might modify views or conclusions presented herein.

A problem related to RIW research was a lack of available literature. Considering the length of time since the first RIW (1967), and the large amount of publicity given to the concept, the scope of literature available is considered to be very specialized on a few issues! Many studies and reports used by this researcher were found to be collections of information from previous literature and many were considered outdated for the purposes of this research.

This thesis assumes the reader has an understanding of the concept of warranties. Although background information is provided as part of this document, the reader will improve his comprehension of the issues presented here if the primary literature referenced is reviewed.

E. METHODOLOGY

The research for this thesis was accomplished primarily through literature review and interviews/discussions with personnel involved or potentially involved in RIW policy and operations.

1. Literature Review

The literature search began with a Defense Logistics Studies Information Exchange (DLSIE) screen of warranty and

reliability improvement warranty descriptors. This proved to be of limited assistance, providing only background and historical information. Many of the references received from DLSIE were simply outdated. Many contracted studies have been done by ARINC Research Corporation. Their reports were valuable in obtaining data and statistics for specific warranties and warranty studies. Mr. Harold Balaban is one of ARINC's current experts on RIW and authored several reports. The Rand Corporation also completed a study for the Air Force in 1977. The report of that study, Reliability Improvement Warranty for Military Procurement, was used extensively, particularly for its convincing opposition to RIWs.

Within the Navy, NAVAIR and the Navy Aviation Supply Office (ASO) have produced most of the written material on the RIW. The files at Naval Material Command (NAVMAT) and Mr. Oscar Markowitz of ASO yielded much of the Navy-related material. Mr. Markowitz proved to be a wealth of RIW knowledge. Particularly interesting was the referenced MID Contract Review of the ASO warranty contract with Abex Corporation, authored by Mr. Markowitz. Other very valuable sources of policy and planning information were internal memoranda within the Department of Defense, Department of the Navy and the Tri-Service Reliability Support Incentives Group [Ref. 15:1].

This material served to provide extensive background information on RIW development and an understanding of the basic RIW issues. It armed this researcher with the ability

to hold intelligent discussions and interviews with personnel directly involved in RIW matters.

2. Interviews and Discussions

In-depth research of the current controversy and issues concerning the RIW required direct contact with the personnel involved. To accomplish this, a two-week fact-finding trip was made to Washington, D.C. Contact was established with the NAVMAT Reliability and Maintainability Office which acted as the coordinator for the visit.

The first interviews were held with four engineers at NAVAIR. These interviews consisted of unstructured discussions from 30 minutes to two hours in length. The purpose of the NAVAIR interviews was to discuss general RIW management and problems with people who had "hands on" RIW experience at the operational level. These interviews provided excellent detail regarding practical problems and advantages of RIW use.

The next series of discussions were held with the reliability staff at NAVMAT. They tended to be both formal and informal since the research was being conducted from that office. The NAVMAT contact provided insight into the foundations for current policy (or lack of it) and future Navy involvement.

Finally, efforts were turned toward NAVSEA where interviews were held with six Reliability Group personnel. Naval Sea Systems Command contains three sections which have reliability and maintainability responsibility: Surface, Combat Systems and Undersea. The Combat Systems group proved

to be the most lucrative contact within NAVSEA. Discussions with the NAVSEA people centered around the various equipments managed by the groups, the working organization within each group, and possible RIW application to the equipments. Since NAVSEA had little actual experience with the RIW, these interviews were held last to give this researcher the advantage of information gained at the other commands.

In addition to the Washington fact-finding visit, telephone interviews were conducted throughout the research effort. Other organizations contacted included: Navy Aviation Supply Office, Air Force Systems Command Headquarters, Army Material Command, Office of the Secretary of Defense, Office of the Assistant Secretary of the Navy (Manpower, Reserve Affairs and Logistics), and ARINC Research Corporation.

F. DEFINITIONS

Much of the confusion surrounding the RIW controversy focuses on definitions for the various warranties. For this reason, careful attention must be given to the definition intended when applying a name to a particular warranty type or clause.

1. Classic Definitions

a. Reliability Improvement Warranty (RIW).

The often quoted definition for RIW is stated as:

> The contractor is provided with monetary incentive throughout the period of the warranty, to improve the production design and engineering of the equipment so as to enhance the field/operational reliability and maintainability of the system/equipment; and

> The contractor agrees that, during a specified or measured period of time, he will repair or replace (within a specified turn-around time) all equipment that fails (specified to subject exclusion, if applicable) [Ref. 18:5].

b. Failure Free Warranty (FFW)

The original term given to the RIW concept. It was later considered a misnomer since it was not a warranty against failure [Ref. 12:16].

c. Mean-Time-Between-Failure (MTBF) Guarantee

A MTBF guarantee requires a manufacturer to guarantee that a stated mean-time-between-failure will be experienced in operation. Failure to meet a guaranteed level requires corrective action by the contractor. An MTBF guarantee is often procured in association with an RIW [Ref. 4:2-7].

d. Reliability Assurance Warranty (RAW)

This term was developed by NAVAIR to distinguish it from the RIW in cases where reliability growth (improvement) is not required [Ref. 12:16].

e. Long Term Warranty (LTW)

A contractual provision which includes the concepts of RIW and RAW. Under an LTW, the contractor is bound by a firm fixed-price contract and is responsible for repair or replacement of a defective item within a specified turn-around time. He is also encouraged to identify and effect engineering changes in order to improve product reliability and maintainability in the fleet [Ref. 13:1].

2. Terminology Problems

Many of the problems encountered in discussing warranties were caused by misleading impressions and judgments

created by current terms. The most common term subject to misinterpretation was the word "improvement" in Reliability Improvement Warranty. It was often associated with "get well" programs resulting from poor engineering development or government supervision. Although this was the purpose for the original RIW contract, the RIW has grown into a much broader concept. The NAVAIR term, Long-Term Warranty, was an attempt to circumvent the widespread terminology confusion. One NAVAIR interviewee stated that "...you must structure each individual warranty to accomplish the desired result in that particular application" [Ref. 3].

3. Warranty Definition

Regardless of the terminology used (RIW, RAW, LTW, FFW, MTBF Guarantee), the basic Reliability Improvement Warranty is a fixed-price, long-term repair contract. For the purposes of this thesis, the term RIW will be used in reference to all contractual warranty types (except standard commercial warranties) unless otherwise specified. The definition used is the Department of Defense definition quoted during an interview. That definition is as follows: "(An RIW is) a system where the contractor is incentivized or penalized for reliability performance in the field" [Ref. 4].

G. ORGANIZATION OF THE STUDY

Chapter II presents the objective of applying the RIW concept to acquisitions. Basic guidelines for determining when an RIW should be considered are provided and the process

of fitting the RIW planning into the acquisition cycle is outlined. Chapter II gives a brief history of RIW development and a synopsis of the Navy applications of RIWs. Chapter IV reviews policies of applicable Navy organizations and summarizes recent studies which have influenced those policies. Chapter V discusses the important major issues affecting RIW expansion. This includes viewpoints on the effectiveness of the RIW gathered from literature and interviews and a look at possibilities for shipboard application of RIWs. Chapter VI presents conclusions drawn from the research, recommendations for improvement of RIW experimentation, and observations of this researcher regarding other areas of study.

II. FRAMEWORK

A. OBJECTIVES OF THE RELIABILITY IMPROVEMENT WARRANTY

The warranty or guarantee concept has its roots in the commercial sector, the Uniform Sales Act of 1906 being the source of warranty-law principles. The original objective of the commercial warranty was to provide protection to the consumer in that he is entitled to receive the product and quality that is expected. Although the Uniform Commercial Code and the Magnuson-Moss Warranty Act of 1975 have updated the warranty laws since then, the basic objective has remained unchanged.

Although the RIW concept is based upon basic warranty principles, the objectives have evolved into more than consumer protection. This evolution has occasionally caused misunderstanding and misguided assessments of the RIW approach. The original efforts with RIWs were to select equipment which was demonstrating poor field reliability and try to improve it through the fixed-fee repair contract approach. The philosophy then shifted from one of fixing a product once it is proven to be bad to one of trying to build it right the first time. This started the movement of RIW application earlier in the acquisition cycle [Ref. 7:4].

Two other warranty objectives of the RIW have been voiced. It may be viewed simply as an insurance policy providing enforceable protection against poor reliability or it may be

3. The equipment is readily transportable or can be field-serviced by the contractor.

4. The equipment is self-contained, immune from failures induced by other units, and has easily defined failure characteristics.

5. The equipment application in terms of expected operating time and environment are known.

6. The equipment is susceptible to being contracted for on a fixed-price basis with form, fit, and function stipulated when practical.

7. The contract can be structured to provide coverage for a period of three to five years.

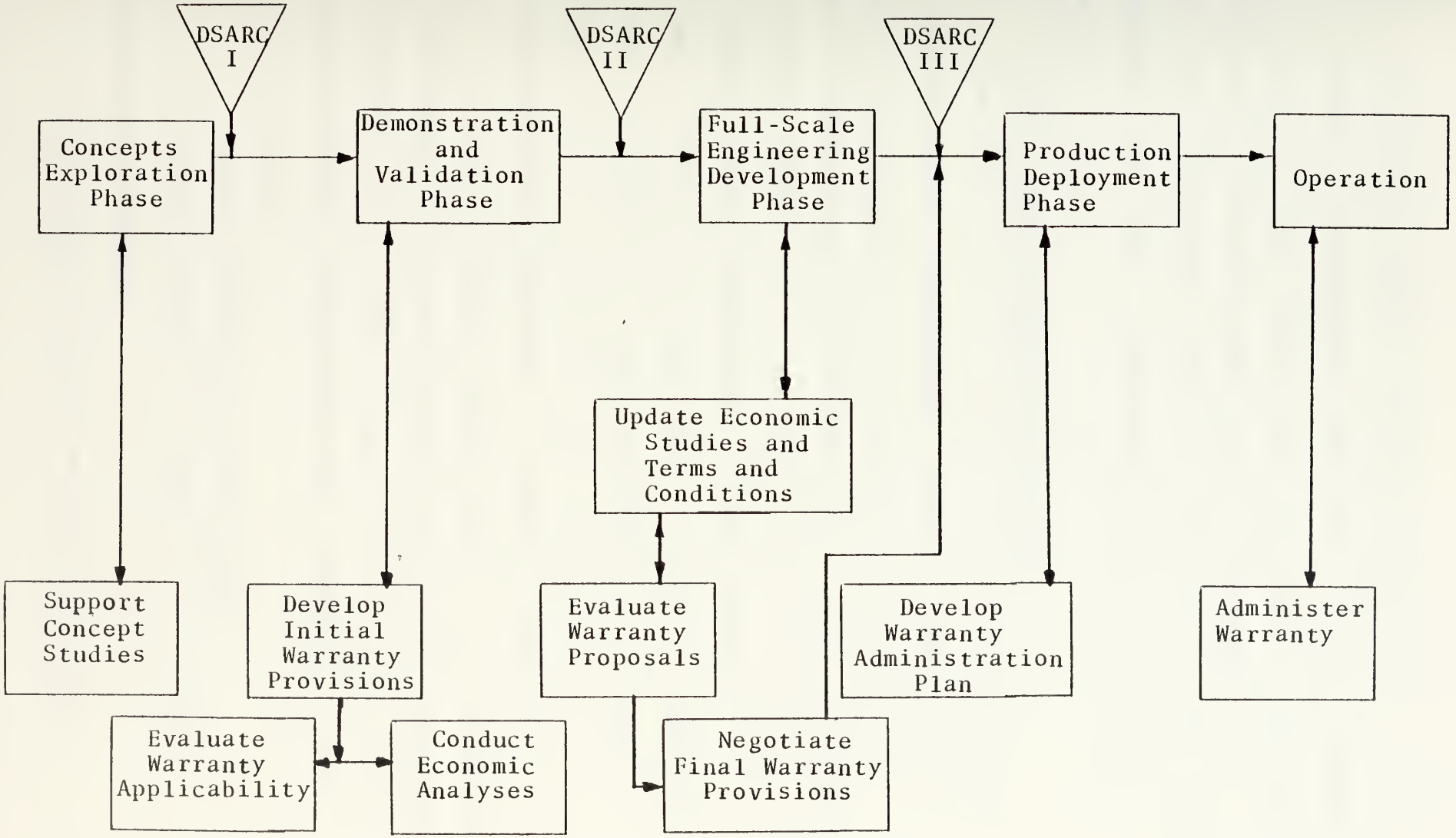
8. The equipment has a potential for both reliability growth and reduction in repair costs.

9. Potential contractors show a willingness toward acceptance of an RIW.

C. RIW AND THE ACQUISITION PROCESS

The motivation desired from RIW application is most effective when the warranty is considered as early as possible in the system's life cycle. A decision to use a warranty will affect equipment configuration and design as well as the planning needed to maintain and support the warranted item. Figure 1 shows how warranty-related activities interface with the system development cycle for major system procurements. The text provided below was condensed from the NAVAIR RIW instruction [Ref. 13:10].

WARRANTY AND THE ACQUISITION PROCESS



Source: Naval Air Systems Command Instruction 13070 (Draft)

FIGURE 1

1. Alternative Concept Exploration Phase

During the conceptual phase, the system is considered in very general terms. Background studies may be conducted on reliability and maintainability and the expected life cycle costs. Warranties should be considered in these studies, along with other means of achieving reliability and maintainability goals.

2. Validation and Demonstration Phase

The validation phase begins with the decision that the capabilities of the proposed system are needed; that a program office should be established; and that resources should be expended on technical and cost analysis, engineering design, and further system definition. The consideration for reliability and maintainability requirements should be included. It is not only important to consider requirements but also how reliability and maintainability can best be achieved. It is at this point that a potential system developer should be made aware if the RIW is being considered since it may affect initial design efforts. It is recommended that the Request for Proposal (RFP) for the Full-Scale Engineering Development Phase (FSED) contain discussion of possible warranty provisions during production. Activities related to the RIW include:

a. Initial screening of RIW criteria.

b. Economic analysis to determine the economic feasibility of a warranty.

c. Development of basic warranty provisions.

d. Fiscal planning to include RIW funding requirements.

e. Incorporation of possible warranty provisions into the FSED RFP.

f. Proposal review in relation to RIW provisions of the RFP.

g. Development of final RIW provisions.

3. Full-Scale Engineering Development Phase

During the FSED phase, the system is designed, assembled and tested to determine if the required operational capability can be achieved within allowable costs. Also, better estimates of system reliability and maintenance support parameters become available. Warranty provisions can also be updated. At the end of FSED, warranty proposals provided by the contractors are evaluated and a final decision can be made to utilize a warranty. Specific warranty steps include:

a. Update of warranty feasibility studies.

b. Development of final warranty provisions.

c. Incorporation of warranty provisions in the production RFP.

d. Proposal review with respect to production proposal warranty response.

e. Warranty decisions.

4. Production and Deployment Phase

With the decision to proceed with production, a number of warranty administration tasks are required. The major tasks are listed below:

a. Development of item-management procedures.

b. Establishment of plan for user indoctrination of processing warranted equipment.

c. Coordination of in-plant inspection requirements.

d. Development and employment of the data system required by the warranty.

e. Coordination of contract administration requirements.

f. Engineering change proposal (ECP) processing.

g. Contractor maintenance facilities review.

h. Technical data review as associated with warranty requirements.

III. BACKGROUND

A. HISTORICAL DEVELOPMENT

The concept of RIW was first applied in 1967 by the airline industry. Pan American Airlines became concerned about reliability risks associated with the purchase of the new Boeing 747 aircraft. In order to attain reasonable support costs for their newly acquired 747s, Pan Am was willing to pay their vendors a fixed amount per flying hour to pass the risk of high support costs. This "total product support" concept incentivized Pan Am's suppliers to build reliability into the aircraft and to improve it throughout the warranty period [Ref. 17:11].

By 1973, product support agreements purchased by Pan Am included MTBF guarantees. The guarantee provided that specified MTBFs would be achieved by the end of the warranty period. If the specified MTBF was not met, the vendor was required to provide additional spares to Pan Am at no additional cost [Ref. 17:12].

In 1967, Lear Siegler, Inc. (LSI) approached the Navy with a RIW-type proposal. Prior to 1967, LSI had been repairing the Navy's 2171 gyroscope used in the A-4 and F-4 aircraft. The repairs had been performed on a cost basis. LSI proposed that a fixed-price, long-term contract be established to overhaul the gyros. This was termed a Failure Free Warranty. The Navy accepted the LSI proposal and a 1500-operating-hour/

five-year contract was established covering 800 of the 3200 gyro population. The contract price was approximately three million dollars. It was considered successful enough that in 1973, it was renewed for an additional 1500 operating hours or six years. The success of this first RIW will be examined in greater depth in a later chapter. However, it was the improvement in reliability of approximately 33% that attracted a great deal of interest within DOD.

The next military RIW was established by the Air Force with LSI in 1969. It covered the F-111 gyroscope for 3000 operating hours or five years. Problems developed with this warranty which made evaluation difficult. The F-111 aircraft experienced difficulties which greatly reduced flying hours and gyro utilization, and the gyro population never reached expected numbers. This warranty is also examined as a case study in a later chapter.

The Air Force and NAVAIR continued with limited warranty application. Warranties were purchased for the AN/APN-194 radio altimeter and the AN/ARN-99 (V-1) OMEGA receiver by NAVAIR. The Air Force applied its second RIW to the AN/ ARN-106 TACAN System. In March of 1973, Rome Air Development Center let a $28,000.00 contract to ARINC Research Corporation for a four-month study of the potential benefits of using reliability-related warranty agreements in defense avionics procurements. Based upon the airline experience and four military warranties, that study recommended the expanded use

of RIW-type warranties [Ref. 5:61]. Since that time, ARINC has continued to be instrumental in shaping RIW development.

As RIW use continued, the DOD Tri-Services Reliability and Support Incentives Group determined that a Warranty Information Center (WIC) was needed to document and make use of the warranty experiences. It was decided that a "pilot" center should be established to answer the many questions about the center's purpose and operation. On 1 July 1976, ARINC Research Corporation was awarded a nine-month contract to establish the pilot WIC. The work was completed between 1 July 1976 and 31 March 1977. The resulting report recommended that a WIC be established on a permanent basis [Ref. 10:1]. That recommendation was never implemented.

After the WIC experiment, the services continued RIW utilization rather independently with the Tri-Services Reliability and Support Incentives Group playing a monitoring role. The Navy's RIW efforts have been concentrated within NAVAIR, which has continued to let warranty contracts when possible.

B. NAVY RIW CONTRACTS

In order to provide insight as to the scope of the RIW program within the Navy, the RIW contracts which have been let or considered are listed. A brief synopsis also provides background information.

1. 2171 Gyroscope

    a. Contractor: Lear-Siegler, Inc.

    b. Dates: 1967, 1970, 1973.

c. Costs of Warranty: $3 million (1967 contract).

d. Synopsis: The 1967 contract was the original RIW contract for DOD. Additional contracts have been let, continuing RIW coverage for the gyros.

2. AN/APN-194 Altimeter

a. Contractor: Honeywell.

b. Dates: 1970, 1972, 1973, 1974, 1975, 1976, 1977.

c. Cost of Warranty: $976,603.00 (1977 contract).

d. Synopsis: This equipment has been purchased under seven RIW contracts. The first 514 were short in duration while the latest covers a period of five years after the delivery of the last unit. Various equipment components also have operating-hour stipulations attached.

3. APN-154

a. Contractor(s): Honeywell and UTE Corp.

b. Dates: 1972, 1973, 1975, 1976, 1978.

c. Cost of Warranty: (Various).

d. Synopsis: The first four contracts had limited two- to three-year RIWs. The 1978 contract provides five-year RIW coverage. The early RIWs produced considerable product improvement. Results from the latest contract were not yet available.

4. F-14 Hydraulic Pump

a. Contractor: ABEX Corp.

b. Date: 1973 (original delivery).

c. Cost of Warranty: $1,595,344.00.

d. Synopsis: The original contract has been amended to include each new production lot of F-14 aircraft. The terminal date is currently 1983. This contract has been rated as highly successful by NAVAIR.

5. AV-8A Hydraulic Pump

a. Contractor: Vickers, Inc.

b. Date: 1976.

c. Cost of Warranty: $35,000.00.

d. Synopsis: The purchase contract provides hydraulic pumps to be retrofitted to an AV-8A aircraft. No warranty results were available at the time of this study.

6. AN/ARN-99 (V) 1 and 4 (OMEGA)

a. Contractor: Nortronics.

b. Dates: 1972, 1974, 1975.

c. Cost of Warranty: $2.9 million (1972), $1.7 million (1974), $1.8 million (1975).

d. Synopsis: These contracts provided short one- and two-year warranty periods. Reliability improvement was accomplished on a consistent basis to the point that the warranty was eliminated on later equipment buys as no longer being cost effective.

7. Variable Speed Constant Frequency Generator

a. Contractor(s): Naval Air Rework Facility, Pensacola.

b. Dates: 1973, 1975, 1976.

c. Cost of Warranty: $209,000.00 (1973), $120,000.00 (1975), $75,000.00 (1976).

d. Synopsis: Warranty provided a minimum coverage of 18 months after delivery unless repeated failures occurred; then coverage was extended to 36 months. The MTBF per flight hour increased from 76 to over 400. Warranty coverage has expired on most units.

8. CH53E Automatic Flight Control Computer

a. Contractor: Hamilton Standard (through Sikorsky).

b. Date: Option developed 1975, exercised 1977.

c. Cost of Warranty: $55,000.00 (Est.).

d. Synopsis: Warranty coverage continues five years after delivery to Sikorsky. Field information was not available at the time of this study.

9. AN/AYK-14 (V) Standard Airborne Computer

a. Contractor: Honeywell.

b. Date: 1976.

c. Cost of Warranty: (20% of hardware cost -- not fully priced).

d. Synopsis: Warranty is for five years on a specified number of operating hours, depending upon module. The warranty option of the procurement contract has not yet been exercised.

10. LTN-72 Inertial Navigation Set

a. Contractor: Litton Systems, Inc.

b. Dates: 1977.

c. Cost of Warranty: $496,620.00.

d. Synopsis: The LTN-72 is a commercial system used extensively by commercial airlines. The contract is a

firm fixed-price repair contract with scheduled improvement goals. However, the contractor is incentivized to reduce maintenance requirements to increase profits.

11. AN/ASN-92 (CAINS)

a. Contractor: Litton.

b. Date: (Contract to be awarded).

c. Cost of Warranty: (To be negotiated).

d. Synopsis: The contract is expected to be a five-year maintenance warranty contract for repair of approximately 900 systems.

12. Harpoon

a. Contractor: McDonnell Douglas.

b. Date: 1976.

c. Cost of Warranty: $4.3 million (through FY-78).

d. Synopsis: The Harpoon RIW resulted from a SECNAV directive that an RIW be included in the contract. The warranty develops through four phases as delivery is accomplished and repair facilities are established. Repair efforts will be based on the failure of periodic built-in-test (BIT) results of deployed missiles.

IV. CURRENT PERSPECTIVES CONCERNING RIWS

The current perspectives of RIWs in the Navy today fill a broad spectrum of policies, recommendations and theories. The research and presentation of these wide-ranging opinions, some substantiated and others not, require a multi-faceted approach. This chapter will present the material which is necessary to consider the position of the RIW in the Navy at the time of this writing.

The materials considered pertinent include studies which were currently influential: policy documents, letters, and memoranda reflecting present guidelines; and the opinions and comments of personnel in management and technical roles.

A. CONTRACTED AND NAVY RESEARCH STUDIES

A number of research studies on the subject of RIWs have been performed by military activities and research institutions under military contract. Many have produced findings and recommendations which have been superseded or are otherwise outdated, and many are repetitive. Two of these studies were chosen as being currently influential and pertinent to the thrust of this thesis and are presented below. Although many considerations in these and other studies and reports have been drawn upon, an understanding of the impact provided by these recent studies is important. Therefore, a brief summary is provided herein.

1. Establishment and Operation of a Pilot Warranty Information Center

The ARINC Research Corporation published a report in April 1977 on a pilot warranty information center which they established and operated for a two-month period as mentioned earlier.

The purpose of the center was to collect RIW information, analyze it, and provide results to the military services for further RIW development. ARINC, in its report, determined that the information was needed to [Ref. 10:2-2]:

a. Establish warranty policies and procedures.

b. Evaluate the effectiveness of warranties.

c. Develop warranty application guidelines.

d. Apply warranty application guidelines by analyzing and recommending whether RIW should be applied to particular planned procurements.

e. Structure warranty provisions and decide which provisions, if any, should be incorporated into contracts.

f. Define and resolve general problem areas such as administrative, funding, and legal aspects of a warranty.

g. Identify specific problems experienced in on-going RIW contracts to prevent their occurrence in future procurements.

h. Support special warranty studies to expand and improve the application of warranties.

The warranty information center was operated during February and March 1977; 59 requests for information were

received and filled. Data on 18 warranties were collected and utilized to make up the output products. The products included [Ref. 10:6-2]:

a. Program descriptions.

b. Performance summaries.

c. Case studies.

d. Warranty provisions.

e. Contract matrix.

f. RIW terminology guide.

g. RIW bibliography.

A critique form was provided to all customers making requests for products to aid in evaluation of the center. Responses were mixed with overall comments being favorable. Recommendations included [Ref. 10:6-10]:

a. "Performance information is needed on more contracts and in more detail."

b. "Reports cited in the bibliography should be available from the center on a centralized basis."

c. "You appear to be collecting information already available in DOD. What is needed is collection of more data and evaluation of these data to provide 'lessons learned' relative to RIW applications."

The ARINC Report made a number of recommendations. The primary thrust of these recommendations was to continue the center on a test basis to collect and analyze data. Since that time, the center has not been reestablished.

2. NAVAIR Study Report on RIW Policy and Implementation

The objective of this study was to investigate the suitability of Reliability Improvement Warranties for NAVAIR applications. Through extensive historical comparisons of Army, Navy, and Air Force data, literature reviews, and interviews, this study details many pages of findings and recommendations. Many of these findings apply to internal NAVAIR management and policies of RIW programs and will not be considered in this thesis. However, those considered broad enough in scope or having significant external ramifications are provided [Ref. 12:18]:

a. There is no centralized source of collected RIW data and information at NAVAIR. There are pockets of warranty expertise and information but gaps exist that should be bridged.

b. The RIW concept is not yet universally accepted by the R&M community.

c. There is a lack of management commitment to controlled RIW experimentation in the Navy. No organization has taken a leadership role in directing and shaping the RIW programs so as to assess the actual value to the Navy.

d. The RIW program is not an urgent requirement nor a crash effort. However, it deserves more management attention and disciplined approach than it is now getting.

e. The implementation of RIWs by the military establishment has primarily been with contractors having commercial airline warranty experience. This has undoubtedly

aided in the success of the applications and may be a partial explanation as to why NAVSEA and NAVELEX have not progressed significantly with RIWs.

f. The specifics of warranty contracts are extremely flexible and can be adapted to fit any number of equipments or situations. However, this necessitates great care to ensure that RIW provisions are not applied disproportionately to either the government or the contractor.

g. Both the Army and the Air Force report that contractor efforts to improve profits by withholding reliability during development to allow for greater reliability improvement after deployment have been neither detected nor suspected.

The consideration provided in the following assessment by the NAVAIR report is one that was expressed by many people in many organizations.

> It is still too early to tell if RIW is right for NAVAIR. Even the Army and the Air Force, who have made management commitments to RIW, are not prepared to answer if RIW is a viable procurement method. Not enough experience has really been accumulated and evaluated. In concept, RIW is desirable. In practice, it has appeared to be successful. However, it has taken dedicated efforts to properly structure and administer RIW programs as it is a new concept and still evolving. The myriad of details involved in RIW are much more subtle and complex than might be assumed from a simple "fixed fee multi-year repair contract" [Ref. 12:49].

B. THE RIW CLIMATE IN THE DEPARTMENT OF DEFENSE AND NAVY COMMANDS

Representatives of the Department of Defense, Office of the Secretary of the Navy, and the Navy's Systems Commands

have expressed varied attitudes and opinions on the subject of the RIW. A review of these policies and opinions (or lack thereof) was made in order to present a proper perspective of RIWs. Where official policy directives were available, they were utilized. However, when written policy was not available, the information was obtained through interviews or discussions with personnel in the various commands. Therefore, much of the "policy" is not from official channels but rather is constructed from organizational practice.

1. Department of Defense

The Department of Defense has displayed renewed interest in RIW development. On 14 November 1978, the Undersecretary of Defense (Research and Engineering) sent a memorandum to each service requesting information to enable joint evaluation of the impact of the RIW program. The memo requested that each service provide a description of the current status of RIW contracts within that service, an analysis of the effectiveness of this type of warranty, and an assessment of desirability for a joint collection and analysis center for warranty information. The responses to this memo were provided to DOD but have not been released. A long-time activist in military RIW involvement and a former chairman of the Tri-Services Reliability and Support Incentives Group provided some insight into the responses submitted by the Army and Air Force. According to this source, the Air Force displayed guarded optimism and recommended establishment of a joint information center, while the Army was less optimistic

and did not recommend a joint center. He also commented on the policy of the Department toward the RIW, stating that it "...is a trial application, still being evaluated." He further implied that while pilot programs are still being evaluated, DOD has neither restricted nor encouraged the establishment of additional warranties [Ref. 4].

2. Naval Material Command

Contact with the Naval Material Command (NAVMAT) was made through the Reliability and Maintainability Office. This office is responsible for providing policy to, and monitoring the performance of, the Navy's Systems Commands in the area of reliability and maintainability (R&M) for their systems procurements. No written policy regarding Reliability Improvement Warranties was available from NAVMAT; however, extensive discussions with these personnel indicated a negative attitude toward the RIW as a viable method of improving field reliability. The Director of the R&M office did express some viewpoints which tend to govern the attitude of the command. He stated:

> My policy is that I am not against warranties or guarantees if we can get them (from contractors). Reliability Improvement Warranties (in the strict definition) are current "gimmicks" with which some think we get something for nothing. Others think we get nothing for something (with RIWs). I think (RIWs) are somewhere in between [Ref. 10].

He also expressed his opinion that future electronic systems will be less and less subject to reliability growth. Continuing advancements in micro-electronics, he suspects, will make repair of electronic modules impractical. He can

visualize systems in the near future where "entire computers will be unplugged from a circuit card, replaced, and tossed into the trash can" [Ref. 10].

The prevailing attitude among the engineers in the R&M office was that the RIW connotated that a system initially was not designed properly. "Put the money up front to design a system properly and you won't need an RIW," was a quote often heard. In response to the increased recognition of the need to improve field reliability in Naval systems, NAVMAT has launched its own program to accomplish that improvement. Termed by some as the "New Look" in reliability and maintainability, this program deserves coverage in a study of RIWs because it is an alternative to such warranties. As described by the NAVMAT reliability engineers, the "New Look" approach places more attention on building reliability into a system, rather than improving reliability once the system is deployed. This is accomplished through design efforts, component selection, quality control, and improved test and evaluation techniques. Direct Government involvement and additional development funding in the "New Look" program replace the motivative influence of long-term repair commitments in RIW programs. The Navy's F-18 aircraft is the first major system being procured under the "New Look" program.

3. Naval Air Systems Command

The Naval Air Systems Command (NAVAIR) and their procurement activity, the Navy Aviation Supply Office (ASO),

have been the Navy's only active users of RIWs. Since the first military RIW contract, developed by ASO, NAVAIR has considered the warranty a workable contracting tool to reduce life cycle costs and improve field reliability. The NAVAIR and ASO have developed rather advanced warranty techniques and are in the process of promulgating internal RIW policies and working guidance. An ASO field instruction provides special procedures for the shipment, receipt, and reporting of equipment under RIW contracts [Ref. 16:1]. The Naval Air Systems Command is drafting an instruction which, when complete, will provide policy guidance and assign responsibility for determining the need for, and applying on a trial basis, Long-Term Warranty (LTW) provisions [Ref. 13:1].

The policy of NAVAIR is to apply the LTW concept on an experimental basis to contracts for the procurement, modification, or repair of weapons systems, equipment, or components whenever it is determined to be advantageous. The instruction also states that the "application of an LTW does not negate the need for good configuration management and sound R&M design and development fundamentals" [Ref. 13:2].

Discussion with NAVAIR personnel revealed a generally high regard for the RIWs with which they have had close contact. The Director of the Navigation and Instrumentation Branch was one of the most adament and experienced supporters of the RIW. It was his firm opinion that contractors must be incentivized, through profits, to ensure maximum reliability

of their products. He considered the requirement for a contractor to repair his products, through warranty, an excellent method of equating reliability with profit [Ref. 3].

This positive attitude toward warranties was exemplified throughout the interviews with NAVAIR personnel. The primary problems with expanded RIW usage concerning the NAVAIR organization were those of internal warranty planning and administration. Specifically, "Who should perform what functions?" and "Who makes which decisions?" According to the author of the NAVAIR Instruction, those problems were being worked out and would be included in a slight revision to their draft instruction [Ref. 8].

4. Naval Sea Systems Command

The Naval Sea Systems Command (NAVSEA) has yet to enter into the RIW area on an active basis. The only written reference to the RIW which could be found by this researcher appeared in a proposed Program Support Agreement with the Navy Ships Parts Control Center (SPCC). In this document, two passages refer to RIWs as follows [Ref. 14:9]:

> SPCC will assure that reliability, maintainability, quality, configuration control, value engineering, life cycle cost (including Reliability Improvement Warranties) are incorporated in appropriate procurements for shipboard material.
>
> SPCC will have the responsibility to identify items which can provide logistics, life cycle cost and readiness advantages utilizing Failure Free Warranty (FFW/ Reliability Improvement Warranty (RIW) procurement techniques. SPCC will provide annual budgetary estimates for the implementation of FFW/RIW, make cost effectiveness

studies and coordinate with the contractors until viable, cost effective proposals are available. The proposals shall be coordinated with NAVSEA for approval and funding. Upon approval, SPCC shall obtain appropriate contract coverage and supervise achievement of contract objectives.

This reference to warranty application in a Support Agreement between SPCC and Naval Sea Systems Command has not actually been promulgated. Such responsibility being placed upon Ships Parts Control Center would significantly enlarge its mission and require additional staffing. This and other problems have prevented the proposed agreement from being approved.

Notwithstanding the above, NAVSEA has no written RIW policy and has been very reluctant to participate in warranty development. A NAVSEA representative accurately summarized their attitude by saying, "(NAVSEA is) not recommending RIWs for shipboard use" [Ref. 6]. A number of valid problems to shipboard use of RIWs influence the negative approach by NAVSEA which will be covered in detail in a later section.

C. SUMMARY

Chapter IV examined the organizational attitudes, approaches and policies of the Department of Defense and, more specifically, applicable major commands of the Navy.

Section A presented brief summaries of two major studies which have strongly influenced RIW opinions and advancement. The first is a report on the Warranty Information Center to improve the basic knowledge of RIW application and provide that knowledge to requesting organizations. The second

study was conducted for the purpose of investigating the suitability of RIWs for NAVAIR and concluded that the RIW was a desirable concept but that additional effort was required to fully understand the complexities of its development.

Section B reviewed the policies and approaches of DOD and major Navy commands. DOD has renewed its interest in trial applications of RIWs as an effort to reduce military spending. The Naval Material Command has not produced policy directives on its usage and has not presented an official stance on the RIW issue. The NAVMAT Reliability Office is favoring the "new look" approach of improving engineering through directly funded, intensified engineering development and product testing. The NAVAIR has initiated RIW application and has developed the Navy's base of expertise in this area. It has further drafted a comprehensive instruction on RIW policy and application. The NAVSEA has recognized the existence of RIWs but has not applied such a warranty to any acquisitions. A program support agreement with SPCC specifies that SPCC should consider RIWs in its procurements.

Chapter V will examine various factors and opinions concerning the actual effectiveness of RIWs and the aspects of expanding its application to shipboard systems.

V. MAJOR RIW ISSUES

The future of Reliability Improvement Warranties in the Navy and the entire Department of Defense is a very controversial subject. Disagreement can be found regarding almost every major RIW consideration. Each major Command or Department has both proponents and opponents of RIWs. In approaching the authoritative and knowledgeable people in the various organizations with the basic research questions of this study, many valid arguments and concerns were raised on both sides of the issue. These positions are the center of the current overall RIW controversy and should be examined.

Two broad areas of concern became the focal point of the research effort: the ability of the RIW to accomplish its intended purposes and the suitability of expanding RIW experimentation into shipboard systems.

A. THE EFFECTIVENESS OF RIWs

The policies and actions of the major commands affected by RIW development reflect the most fundamental and deep-rooted controversy of the RIW subject. Is RIW a valid concept for accomplishing the objectives for which it is designed? Many arguments can be made for either a "yes" or "no" answer to this question.

This section of Chapter V will present three basic viewpoints from which to examine the question of RIW effectiveness. The first will be the commercial foundation on which the

military organization adopted the RIW concept; second, various viewpoints of members of the Navy's reliability community will be compared; and third, four brief case studies will be presented. Although many other questions of RIW application, administration, funding, and specifications also remain unanswered, the basic effectiveness must first be determined to some degree of satisfaction.

1. Commercial versus Military Application of RIWs

a. The Commercial Basis for Warranties

The basis for warranty development originated in the commercial marketplace and has grown through commercial laws and regulations. The military's use of warranties to motivate contractors to improve the reliability of products has often been justified on the basis that (1) consumer product warranties have provided the customer with a more reliable or higher quality product, and (2) warranties shift the risk of repair or replacement costs from the buyer to the manufacturer. Both assumptions are generally incorrect [Ref. 11:38]. Generally they have been used as a promotional device or as a protective device to limit liability through exclusions and disclaimers. In either case, warranties protect the seller's interests more than the consumer's [Ref. 11:35].

The standard automobile warranty is a familiar example of this theory. The Federal Trade Commission published a "Staff Report on Automobile Warranties" in 1968. This report concluded [Ref. 11:36]:

(1) The industry deliberately over-sold its improved warranty in the 1960s, creating the impression that "higher levels of engineering and manufacturing skill" had overcome the complexity of the automobile.

(2) Warranty extensions had no correlation with quality or developments in engineering and manufacturing.

(3) Quality control and warranty performance were declining.

b. Commercial Airline Avionics

Chapter III pointed out that the first RIW-type warranty was used by the commercial airline industry. The airlines continued to develop the concept and have put it to successful use. It is the airlines' use of warranties on commercial avionics equipment that has been cited so often as the basis for the use of RIWs by the military services. An ARINC Research Corporation study concluded that RIWs in commercial avionics procurement are a major factor in producing higher equipment reliability [Ref. 5:54].

Some factions argue, however, that commercial experience does not justify the strong support given to it by the military. These arguments take two forms: (1) the improvement in reliability of commercial avionics equipment cannot be totally credited to warranty application, and (2) too many dissimilarities exist in commercial and military environments to compare possible warranty results.

The same 1973 report by ARINC Corporation concludes that it is generally recognized that airlines obtain

a higher reliability than the military achieves with functionally comparable equipment by a factor of 5:1 to 8:1. However, it also states: "...The airline's ability to maintain competition into the equipment production phase accounts for a major portion of these observed ratios." The report also concludes. "Most vendors believe that there is definitely an incentive (from warranties), but it is difficult to separate it from the incentive that competition produces" [Ref. 5:55].

The Council of Defense and Space Industry Associations (CODSIA) has expressed concern for the differences in commercial and military warranty applications. They contend that the sophistication and state-of-the-art design of military equipment have a direct bearing on the risk involved on the extended use of warranties. Table I highlights some of the basic differences between commercial and military products in the following areas [Ref. 8:2]:

(1) Design of product.

(2) Use of product.

(3) Environmental surroundings.

(4) Storage.

(5) Maintenance and repair.

They also state that commercial warranties impose only limited financial risk spread over a larger production base than military warranties.

These arguments tend to dilute, though not destroy, the justification of warranty usage by the military services on the basis of higher reliability in commercial avionics.

TABLE I

DIFFERENCES BETWEEN DEFENSE AND SPACE, AND COMMERCIAL PRODUCTS, IN THEIR DESIGN, USE, ENVIRONMENTAL SURROUNDINGS, STORAGE, AND MAINTENANCE

A. DESIGN OF PRODUCT

Designs usually are geared to the following objectives in order of priority:

	DEFENSE AND SPACE		COMMERCIAL
1.	Improved performance capabilities involving advancements in the state of the art.	1.	Simplicity of equipment to permit foolproof operation.
2.	Continuous operation of equipment under extreme environmental and working conditions.	2.	Competitive performance capability.
3.	Extremely limiting space and weight restrictions.	3.	Lowest possible cost.
4.	Reasonable cost.	4.	Reasonable equipment life assuming normal use under average conditions.
5.	Possible long-time storage before initial use.	5.	Ease of maintenance.
6.	Design changes continue after production begins.	6.	Design is completed and frozen before production begins.

B. USE OF EQUIPMENT

	DEFENSE AND SPACE		COMMERCIAL
1.	Moderate pre-purchase testing.	1.	Extensive pre-purchase testing.

B. USE OF EQUIPMENT (continued)

DEFENSE AND SPACE	COMMERCIAL
2. Normally used under the worst possible field conditions at extremes of temperature, etc.	2. Normally used under the best possible field conditions designed for the comfort of the user.
3. Operated by people who have little or no motivation to "preserve" the equipment.	3. Operated by people who are highly motivated to "preserve" the equipment either because of ownership or in the interest of job retention.
4. Because simplicity of design usually is not a primary objective, operation of complex equipment is normally also surrounded with equal complexity. Operational training is normally inadequate and never keeps pace with design and resulting operation changes.	4. Because the equipment was originally designed with ease of operation in mind; this plus the greater experience and training of operators make for fewer field problems.

C. ENFIRONMENTAL SURROUNDINGS

DEFENSE AND SPACE	COMMERCIAL
1. The location of ultimate field use of the equipment is rarely, if ever, known and designs must therefore make provision for extremes in temperature, humidity, equilibrium, vibration, maintenance and repair, etc.	1. The approximate location of ultimate equipment use is always known. If the same TV model is to be distributed for sale in Canada and the tropics, suitable adaptive changes are made in the products sent to different areas.
2. Because of the ever-increasing need for greater economy in defense, there is an increasing desire for multiple usage of equipment--for example, aircraft suited to both land and sea warfare; communication equipment usable in aircraft, on the ground, and under the sea, etc.	2. Extremes in physical conditions of use, such as excessive vibration, etc., are rarely encountered.

(continued)

D. STORAGE

DEFENSE AND SPACE	COMMERCIAL
1. Many of the products purchased by NASA and DoD are for long-time storage before actual need and use. Damage sustained during this period of idleness is extremely difficult to isolate and distinguish from the causes of malfunction in later use. Mishandling during storage can be a major cause of later dysfunction.	1. On-the-shelf storage of commercial products before sale and use is of short duration.

E. MAINTENANCE AND REPAIR

DEFENSE AND SPACE	COMMERCIAL
1. Frequently attempted by inadequately trained service personnel under adverse field conditions and with improper or inadequate facilities and tools.	1. Usually performed by competent personnel under favorable shop conditions.
2. Subsequent attempts to place the blame for equipment malfunction where it properly belongs are either difficult or impossible.	2. Usually easy to determine whether malfunction of equipment was because of product failure or user abuse.
3. The cost of improper maintenance and repair is exorbitant and the equally high cost of settling the responsibility for malfunction added to it make the enforcement of express warranties non-cost effective in the extreme.	

SOURCE: CODSIA.

2. Reliability Community Viewpoints

Within the Navy, various reliability and maintainability (R&M) groups concern themselves with the problems of equipment reliability and the most efficient and cost effective methods to improve it. It is within this R&M community that the RIW controversy is centered.

An attempt to simplify the numerous and confusing issues was made during interviews and literature review. As a result, the fundamental philosophic differences began to appear. Both the proponents and opponents of RIW usage are in agreement on what actions are necessary to improve equipment reliability. Briefly, those actions include the improvement of product design with more emphasis on R&M and the development of more suitable test and evaluation procedures to stimulate extended field usage. They also agree that these improvements can be accomplished with reasonable success.

The philosophies began to diverge, however, regarding how to accomplish the desired actions in the government acquisition arena. The proponents of the RIW expound the belief that a warranty provides a needed incentive for the contractor to improve R&M design and testing, not as a substitute for, but in addition to other government project management. Those opposing argue that RIWs provide no real incentive to a contractor and that money spent on RIW clauses is more appropriately needed to buy additional design and testing directly.

The basis for these philosophies lies in the attitudes of the personalities involved. These attitudes reflect years of differing experiences and are set deep enough that change will prove difficult. A brief examination of both factions in detail should bear this out.

a. Proponents' Viewpoints

The proponents argue that the government is motivated to buy a warranty to shift a considerable part of the technical and administrative burden in design improvement, test and evaluation, active fleet failure surveillance, and identification of design shortcomings from the government to the contractor. To the degree that the contractor can reduce fleet failures, the less fleet time and money are spent in downtime and maintenance actions [Ref. 12:18]. An engineer at NAVAIR exemplified this theory by his statement, "No one in the Navy can design a (modern aircraft) hydraulic pump." His approach was based upon his experience in working with hydraulic design. He agreed that the ability for proper equipment design resided with contractors and that proper incentive was necessary to extract the contractors' best effort [Ref. 9].

Another NAVAIR interviewee provided a slightly different approach for the necessity of warranties. Based on his experience in navigation and flight control systems engineering, he related RIWs to quality control in the manufacturing process. Given that an equipment met reliability

specifications under the most stringent test and evaluation procedures, he pointed out that the testing was usually performed on a prototype or very early production models. However, because the production process can only degrade reliability, the initial test and evaluation would not usually reflect true field reliability. Therefore, an incentive to ensure the maintenance of good quality control throughout production was necessary. According to this interviewee, a warranty contract was a quite logical incentive because it forced concern for future equipment repair onto the contractor, at the expense of possible profits [Ref. 3].

Another NAVAIR engineer directly involved with RIW development expressed a similar viewpoint in a slightly different manner. He voiced the opinion that the "New Look" program (buying additional design and testing with close government involvement) allowed the contractor to forget reliability requirements once an equipment was accepted and production and delivery commenced. This, he considered, would result in degradation of field reliability.

b. Opponents' Viewpoints

Those who oppose the warranty concept base their opposition on the theory that adequate incentive is not provided or necessary to accomplish acceptable reliability. A reliability engineer at NAVMAT expressed strong doubts about the effects a warranty clause has on a contractor's efforts or ability to improve reliability. In his words, "(contractors) don't have a 1000-hr. MTBF engineer, a 2000-hr. MTBF

engineer, and a 3000-hr. MTBF engineer that they can pick from according to how much (government) pays. They are doing the best they can (to increase reliability)" [Ref. 5].

That engineer's opinion follows closely with the reference to automobile warranties made earlier in this chapter and that of CODSIA. In a letter to the U.S. Army Procurement Research Office, CODSIA stated:

> The attitude of the government...is that increased reliability is something solely within contractors' control, and that contractors are failing because of lack of sufficient motivation to build products with the necessary reliability..." [Ref. 8:3].

Another viewpoint, although unsubstantiated by fact or experience, was quite often encountered. Many of the R&M personnel interviewed expressed the fear that the addition of RIW clauses could lead to contractors' taking double profits. According to the advocates of this theory, the contractor could "hold back" on initial equipment reliability while profiting on the production contract and then quickly improve field reliability up to contract goals, earning substantial profit under the RIW repair contract. Although no cases of this type of action have been detected, the logic appears to be valid and should not be ignored [Ref. 12:46].

3. Case Studies

The results of completed and in-progress RIWs are of great concern to the organizations involved. Unfortunately, the RIW experiment has not been easy to control and the results of warranties have not been a simple matter to analyze. Four

brief case studies are presented to exemplify variations of warranty success and the difficulties in determining the extent of success.

a. Navy 2171 Gyro

The Navy's 2171 gyroscope was the first equipment for which a warranty was purchased. Of the Navy's 3200 units, 800 were covered under a Failure Free Warranty contract; the remaining 2800 were under a repair contract. The contract had a goal of increasing the warranted gyros' MTBF from 400 to 520 operating hours over a 1500-hour or five-year period. Interim reports on the warranty were favorable. The 520-hour MTBF goal was achieved two years earlier than predicted. During the same period, the MTBF of non-warranted gyros improved to 442 hours [Ref. 6:176]. Because of lower than predicted utilization, however, the contract was extended for two months beyond the five-year cutoff, at an added cost.

Over the five-year period, only 990,000 operating hours were achieved. As a result, if the original conditions of the contract had been followed, the RIW would have cost the Navy $166,000 more than non-RIW support. However, with the contract extension and other considerations, a NAVAIR study estimated the total savings to be $465,000 [Ref. 6: APP. A]. To add to the confusion, a later RAND Corporation study calculated the overall savings to be only $51,000 on a contract of just over $4.5 million. The RAND study also

pointed out that LSI conducted roughly 50,000 hours of continuous laboratory testing during the contract period. This raises the question of what the cost and result would have been had the test program been financed independent of a warranty [Ref. 11:46].

b. Air Force F-111 Gyro

The Air Force's F-111 gyroscope was the next major contract involving a warranty. The original design and procurement was by General Electric in the early 1960's. The first 534 units were supplied by GE under a sole-source contract. In 1969, the Air Force concluded that low reliability of the gyros necessitated a new procurement using competition. Lear Siegler won that contract for 601 gyros. The new gyros were warranted against failure in that LSI would repair or replace any unit that failed, though no MTBF guarantee or goal was specified. The warranty period ended in 1976.

The non-warranted GE gyros were experiencing an MTBF of 681 operating hours. LSI expected to improve their gyros' MTBF to 1494 operating hours. Many problems were experienced with this warranty, most of which were attributed to the low utilization of the F-111 aircraft. Although the goal was not met, during October 1973 an MTBF of 1214 hours was achieved on the warranted gyros. The non-warranted gyros still in use were experiencing an MTBF of 749 hours during the same period.

Two major factors, not related to the warranty, may have accounted for the improvement in MTBF of the warranted gyros over the non-warranted GE gyros. First, the warranted gyros were produced under competition by a different contractor. This may have been the necessary motivation for improved reliability design. Second, extensive additional testing was conducted during the year before the warranty period. This augmented test program probably improved the gyro's reliability and could have been duplicated without a warranty [Ref. 11:49].

c. Navy F-14 Hydraulic Pump

One of the most successful RIW contracts to date is the Navy's F-14 hydraulic pump with ABEX Corporation. The contract was signed in April 1973 and provides coverage through 982,560 pump operating hours or April 1983, whichever occurs first. The original contract covered 258 pumps and has been amended to cover later lots of F-14 production. The contract specified a reliability growth from an MTBF of 500 hours to an MTBF of 750 hours. The original warranty cost was $846,444.

An Aviation Supply Office contract review published in October 1977 reported the following significant results [Ref. 15:iii]:

(1) Cost Effectiveness (1973-1983)

RIW cost: $1,595,344.

Non-RIW cost: $3,535,842.

(2) Reliability Growth (1973-1977)

RIW: From 500 hours MTBF to 1250 hours MTBF.

Non-RIW: From 500 hours MTBF to 590 hours MTBF.

(3) Fleet Support

RIW: 2.4% of total hydraulic systems NORS (Not Operationally Ready, Supply) allocated to its engine-driven pumps supported with 25% spares.

Non-RIW: 41% of total hydraulic systems NORS (A7-E) allocated to its engine-driven pumps supported with 75% spares.

The report concludes, "This RIW contract has been the most cost effective support alternative available to the Navy" [Ref. 15:44].

The Aviation Supply Office and NAVAIR have judged this warranty as highly successful to this point; however, it has not been problem-free. An interview with the NAVAIR engineer on the project revealed two problems [Ref. 9]. First, it was his opinion that the warranty was put into force too early in the acquisition cycle. The warranty went into effect after delivery of some production units but prior to completion of the aircraft qualification testing. Waiting until the aircraft had completed qualification tests before enforcing the warranty would have, in his opinion, reduced some of the efforts in solving various technical problems. Second, problems have existed with configuration control and failure reporting. He stressed the importance of NAVAIR and Grumman

Aircraft Corporation (the prime contractor) being made aware of failure problems experienced with all aircraft systems and the need for control of equipment configuration. Early in the warranty period, failed units were being shipped directly back to ABEX for repair and the reporting system was not effective. Neither Grumman nor NAVAIR were made aware of some early technical difficulties, the knowledge of which should have been widely distributed. At the time of the interview (July 1979), the reporting problems were less frequent.

d. Navy AN/AYK-14 (V) Standard Airborne Computer

The Reliability Assurance Warranty (RAW) covering the AN/AYK-14 (V) is one of the Navy's newest warranty contract options. It covers the computer, ground support equipment, laboratory equipment and software through a specified elapsed operating time or a period of five years. (The elapsed time varies from 2200 to 5000 hours by equipment.) The contractor will provide materials and services required for total maintenance/improvement of all equipment and software. Both intermediate and depot maintenance will be provided for.

Although the warranty provision of the contract is not yet in force, the Primary Contracting Officer (PCO) is seeing results. He stated that pre-production equipment has displayed "astounding" reliability. MTBF has exceeded that of similar equipment in use by quantum steps [Ref. 7].

The AN/AYK-14 (V) project is also the first acquisition to which the "new look" program has been applied. Although the "new look" program is considered by its developers to be compatible with warranties, the simultaneous application of two unproven programs to accomplish the same goals will make analysis difficult.

e. Observations on the Case Studies

The four case studies characterize many situations found in the RIW program. The key points intended are:

(1) The result of most of the programs has indicated a definite increase in MTBF.

(2) In three of the four preceding cases, none have been problem-free.

(3) In three of the cases, other factors are present which could also have influenced the improvement in reliability.

(4) The actual costs involved cannot always be agreed upon. This also raised questions about the cost effectiveness of RIWs when compared to other methods of reliability improvement.

B. THE APPLICABILITY OF RIWS TO SHIPBOARD SYSTEMS

Most notably absent in RIW development has been the Naval Sea Systems Command (NAVSEA). The RIW has yet to be applied to shipboard systems. There are several reasons for the lack of RIW development in this area which were brought out in discussions with NAVMAT and NAVSEA personnel.

1. Problems Inhibiting Shipboard Application of RIWs

The most evident problems with warranties on shipboard equipments are of a logistics nature. The logistics requirements of a warranty are not generally compatible with the self-sufficiency requirements of a Navy ship. Transportation of failed components to a contractor-designated repair facility is not usually available to a ship at sea. Additionally, the necessity for the repair of failed equipments while a ship is at sea is a real concern. Unauthorized repair by non-contractor personnel might be difficult if repair parts and expertise are not available, and its accomplishment would likely void any warranty.

Another concern expressed by a NAVMAT engineer is one of configuration control. If the RIW provided for contractor improvements of warranted equipments, it is possible to have two sub-components on board a ship which are not internally identical. This could make the emergency repair procedure known as "cannibalization" (making one operable unit from the parts of two or more failed units) impossible [Ref. 10].

One final issue concerns a characteristic of successful RIW application. It is generally accepted that in order for an RIW to be profitable for both the contractor and the government, a large number of systems should be purchased under the warranty. The fact that ships are not purchased in large numbers usually results in major systems being contracted in small numbers or even one-of-a-kind. According

to most people experienced in RIW administration, this makes warranty application to these systems infeasible.

A number of considerations internal to NAVSEA have also impeded the expansion of RIWs to ships. The lack of experience in RIW application and development became evident during discussions with NAVSEA Reliability and Maintainability (R&M) personnel. An interviewee at NAVSEA stated that the Navy Ships Parts Control Center (SPCC) was given responsibility for NAVSEA RIW contracts through a Support Agreement between them [Ref. 1]. The applicable paragraphs of that agreement have been cited in Chapter IV, section B-3. In fact, that agreement has not been approved and no RIW responsibilities have been passed to SPCC. That organization does not have an engineering staff to undertake warranty structuring; nor is SPCC involved in the design, development, or contracting of major systems. The application of RIWs requires interface with all of those processes, which places SPCC in a poor position to structure and contract this type of warranty.

Another R&M group at NAVSEA expressed considerable interest in exploring RIW applications. Their efforts to pursue the matter were hindered, however, by a lack of guidance or understanding of RIW development. There appeared to be little comprehension regarding which organizations should become involved. When questioned about warranties, one interviewee responsed, "We used to write them into the specs years ago but 'they' always scratched them off, so

we just quit asking." When asked who "they" were, he did not know.

While these two examples are extreme, they were encountered in the offices of the organization that should be taking the first look at warranty candidates.

2. The Basics of RIW selection Applied to Shipboard Systems

A review of NAVSEA-sponsored electronic and navigation systems, both operational and planned, with R&M engineers provided interesting results. In this review, very basic criteria were used in the screening process for possible RIW application.

The "basic" RIW questions considered here precede the often published and normally accepted list of equipment characteristics as selection criteria. According to one member of the NAVMAT reliability staff, the first question which must be asked is, "What is the maintenance plan?" [Ref. 2]. A NAVAIR engineer breaks that down into more pragmatic questions: "How does it work? What is likely to fail? How many spares are needed? Who should repair it? How can it be shipped?" [Ref. 3]. This is a much simplified view of the warranty decision, but it accurately depicts the line of thinking an engineer must pursue to start the decision process.

The systems reviewed with NAVSEA R&M personnel included several Ships Inertial Navigation Systems (SINS), both deployed and under development; and computer hardware deployed on the 688 class nuclear-powered submarines. This includes the AN/UYK-7 computer, the IBM RD-281 tape drive, and other input/output devices.

The SINS equipment is all repaired at the depot level. Underway maintenance is limited to major component exchange because the technology prohibits bench repair aboard ship. In some cases, two complete units are operational at all times, and a third unit is stored in special shipping containers for rapid exchange. Failed units are stored in the containers and shipped to the depot when the ship enters port. The complete systems are divided into two or three major components which cannot be broken down further except at the designated repair facility. Also of interest is the fact that some currently deployed models have experienced an MTBF that is only 25% of design specification, according to NAVSEA engineers.

The maintenance plans for the shipboard computer systems have many similar characteristics. The AN/UYK-7 computer, manufactured by Sperry-Univac, has multiple installations aboard several ship types. Although an exact number of planned installations was not available, it was estimated at over 1000. Many of the computer peripheral devices including the IBM RD-281 tape drive, the Sperry OJ-172 I/O terminal, and the Raytheon OU-83 central signal data converter are "off-the-shelf" components purchased in large quantities. The maintenance plan calls for contractor repair under a standard maintenance contract. No warranties were supplied or purchased with these equipments.

Both the navigational equipment and the computer systems display many of the characteristics specified for

RIW candidates. The logistics problems associated with shipboard installation will presumably be overcome under the current Depot/Contractor maintenance plans and would be little additional burden under warranty considerations. These equipments also adhere to the classic requirements. They are generally self-contained, field-testable, and transportable. They are also easily adaptable to elapsed-time indicators and should be subject to high utilization.

C. SUMMARY

Section A presented various viewpoints concerning the effectiveness of RIWs. The foundation of RIW development in the military environment lies in the commercial warranty field and the commercial airline industry experience. Commercial warranties have generally been considered as a protective device for the consumer and commercial airlines have benefitted with higher equipment reliability. However, the argument has been made that commercial warranties provide the most protection to the manufacturers and do not necessarily motivate them to produce a better product. Additionally, differences in the specifications and operating environments, not warranty usage, of commercial and military equipments can explain the apparent reliability inequalities.

The members of the reliability community are also divided as to the effects of warranties on contractors. Proponents of warranties cite the profit motivation of RIWs as the prime mover in producing reliability improvements:

improvements resulting from better design and more intense quality control by contractors. Industry representatives and some military factions argue that warranties provide little incentive and are less cost effective than other methods of buying improvements.

The case studies exemplify another aspect of the warranty controversy. Some warranty applications have apparently been successful in providing motivation to contractors and saving money for the government. However, in some applications, other factors have also influenced the results, making warranty evaluation difficult or inconclusive.

Section B examined the application of RIWs to shipboard equipments. RIWs have not been applied to shipboard equipments because of a number of problems. Primarily, the logistics difficulties in support of operating ships have tended to inhibit warranty possibilities. Supply lines are often too long or inconsistent to transport failed components or replacement spares on a regular and timely basis. Additionally, shipboard systems are usually purchased in quantities too small to make warranty application profitable for contractors.

An examination of some equipments being deployed and to be procured provided ideas for consideration. The advanced technology of navigation and computer equipment has resulted in the necessity for depot or contractor maintenance, reducing shipboard repair to major component exchange. Also, multiple installations and standardization aboard ship have increased the total number of each system procured by the Navy. This

means the logistics problems previously associated with warranty repair are present with current maintenance plans and must be solved, and quantities are high enough to make profitable warranties feasible. These equipments also possess other characteristics desirable for warranty application.

Chapter VI will present conclusions drawn from the material in Chapters IV and V as well as possible recommendations for further warranty evaluation.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. The Navy does not have firm policy guidance on which to conduct effective warranty trial applications.

The Naval Air Systems Command was the only major Navy organization for which written policy and implementation guidance was available. Although the Office of the Assistant Secretary of the Navy (M,RA&L), the Naval Material Command, and the Naval Sea Systems Command have addressed the subject in correspondence and have voiced opinions, none have produced firm policy or guidance to assist their internal staffs or subordinate orginations in the application or use of RIWs.

2. A firm judgment on the effectiveness of the Reliability Improvement Warranty is yet to be made.

Analysis of completed RIW programs has indicated success in most cases. Significant increases in MTBFs have been accomplished at an apparent reduction in total costs. Although many programs have experienced problems, no RIW has been judged a complete failure.

However, many valid questions have been raised concerning the validity of the analyses. Most experts will agree that many of the costs of RIW application and administration have not been quantified. Also, the effects of RIWs in MTBF improvement cannot be distinguished from the effects of other variables which cannot be removed from the experiments. Finally, it is impossible to accurately determine the

success of the overall RIW effort when each program is analyzed individually by the program's sponsoring organization.

3. Reliability Improvement Warranty application to shipboard systems is feasible on a limited, trial basis.

The shipboard systems examined during this research met many of the fundamental criteria for RIW application. No indication was given during interviews with NAVSEA personnel that RIW application was considered as an alternative to depot or standard repair contract support.

4. The Naval Sea Systems Command has an apparent lack of understanding or appreciation for the possible benefits of Reliability Improvement Warranty usage.

Although the reluctance to enter warranty experimentation is founded upon some very real and valid concerns, the potential for warranty implementation is available on a limited basis. However, for that potential to be realized, the proper emphasis must be placed at the level of organization equipped to make knowledgeable warranty decisions. This includes management, contracting, and engineering personnel. Those R&M engineering personnel interviewed displayed an interest in the possible benefits of applying warranty provisions but lacked impetus and guidance for developing or staffing initial warranty proposals.

B. RECOMMENDATIONS

1. The trial application of Reliability Improvement Warranties should continue on a controlled and limited basis.

The RIW controversy cannot be solved if trial application is not continued. However, care must be exercised in controlling the application and in evaluating the results of RIWs. More centralized management of RIW experimentation should allow for improvement in the understanding and application of the information obtained. This improvement is necessary to properly develop and implement future RIW policy.

2. The Naval Material Command should develop RIW policies and functional capabilities which will allow it to become the Navy's central control and evaluation point for warranty experimentation.

The Naval Material Command is the logical organization to control the policies of the Navy's RIW program and evaluate the overall results. Although the operational decisions remain with the Systems Commands, NAVMAT should consolidate and evaluate the Navy's overall RIW success. The current lack of firm policy and organized information have resulted in uncontrolled experimentation and a lack of objective analysis at the NAVMAT level. To correct this, tighter control must be placed upon the application of RIWs and NAVMAT must develop the ability to collect data and objectively analyze the results.

3. The application of RIWs to shipboard systems should be considered as an alternative to depot or contractor repair.

The NAVMAT should coordinate with NAVSEA regarding the limited application of RIWs to shipboard systems. If accomplished under controlled conditions on properly selected systems, the results could further the understanding of RIW effectiveness.

C. OBSERVATIONS AND ITEMS FOR FURTHER STUDY

The following observations and suggestions for further research are the opinions of this researcher gained during the compilation of this study.

1. The proper concept and objectives of RIWs is not uniformly understood within the Navy's reliability community. The "improvement" aspect of the RIW term overshadows other possible benefits, e.g., contractor incentivization and risk-sharing. Many interviewees expressed more than mild opposition to RIWs but were in favor of other warranty types. The Long-Term Warranty used by NAVAIR appears to be an effective method of overcoming this stigma. Therefore, DOD should consider changing the universal term to long-term warranty.

2. The NAVAIR displayed considerable advancement in developing the details of applying and administering RIW contracts. Training of other systems commands, by NAVAIR, regarding proper RIW management could reduce "growing pains" in the expansion of trial applications. The NAVAIR draft instruction for RIW management shows potential as an excellent example for others to follow.

3. The organizations contacted for this research displayed definite bias either "for" or "against" the RIW concept. The objective evaluation of RIW programs cannot be accomplished unless these biases are overcome.

4. The RIW concept is firmly entrenched at the congressional and DOD levels as a viable program for improving reliability in military systems. Until valid

facts are produced which disprove this concept in favor of an alternative, the trial application of RIWs will continue. Only improved management of the program, at all levels, will foster a correct evaluation and benefit the government.

5. The accurate and timely evaluation of RIW trials is one of the most perplexing problems which face the decision makers. This researcher is unaware of any evaluative model being used to improve or standardize the evaluation of RIW applications. Additional research for development of an evaluative model which will improve the ability to compare and standardize RIW results is desirable.

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